The influence of the position of the lower jaw on human performance in athletes

John Haughey

MSc Neuromuscular Therapy

XN7129 - Research Project

Word Count – Paper A: 5,189; Paper B – 4,144

University of Chester

Contents page

Paper A - Literature review of chosen research topic

The lower jaw position and human performance in athletes

John Haughey[1]

[1] MSc student at University of Chester

Word Count: 5,189

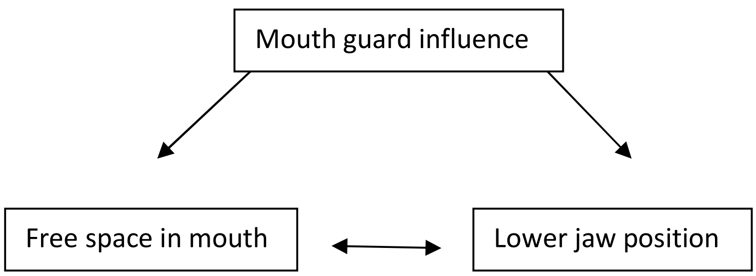
Abstract

Mouth guards are widely used by athletes for the protection of the orofacial region from trauma during training and competition. A mouth guard will change the position of the lower jaw of the athlete when worn. This literature review looked at the findings of current research on the effect of mouth guard use on athletic performance. Studies which investigated the possibility of a negative impact on performance from wearing a mouth guard generally concluded that there is no negative impact on performance. Some other studies suggested there is no impact on performance with mouth guard use in sport and a larger number of studies observed positive influences on performance. The position of the lower jaw during mouth guard use in comparison to wearing no mouth guard is the common reason given for the positive improvement observed in performance. There is a lack of consensus in the current research of the mechanism or connection between lower jaw position and performance. This literature review raises the question, does the position of the lower jaw affect human performance?

Introduction

Mouth guard use is popular by athletes especially in contact sports. The main reason for mouth guard use by athletes is for the protection of the orofacial region from trauma during training and competition. There is a common acknowledgement that there is a benefit of wearing a mouth guard for protecting the orofacial region against trauma during training and competition in sport. It is this protective ability of the mouth guard that has lead to some sporting bodies, for example AIBA in amateur boxing and GAA in gaelic football, making mouth guard use compulsory during training and competition.

When an athlete wears a mouth guard it has a changing effect on their oral environment. The mouth guard takes up free space in the mouth and changes the position of the lower jaw by not allowing the lower teeth to bite against the top teeth. There is no common consensus on what effect these changes to the oral environment have on human performance.



This literature review will look at current research to see if there is a suggestion that there is a positive effect, a negative effect or no effect on human performance by the changes in the oral environment during mouth guard use. It will also look to see if there are any suggested mechanisms that may explain any differences that have been observed.

The scope of the review will be limited to mouth guards used by athletes for sport and will not involve any studies into mouth guards used for other oral health needs.

Review of Literature

Mouth guard use

Mouth guards were first developed to protect boxers from lip lacerations. A London dentist, Woolf Krause, used a rubber material to help prevent lip lacerations which at that time were a common and often disabling accompaniment in boxing.

Due to the focus of the mouth guard preventing a boxer losing the fight due to a lip laceration, it could be viewed that mouth guards were first invented for a performance benefit in sport. This was highlighted in a championship fight in 1921 when the manager of a boxer claimed the mouthpiece the opponent was using is an illegal advantage.

Nowadays mouth guards are commonly used to protect against orofacial injuries in sport with many sports recommending mouth guard use and even some sports making mouth guard use compulsory during competition. Making mouth guard use mandatory can be justified in the research as was expressed in a systemic review carried out by Knapik, et al., (2007) which stated that impact studies have shown that compared with no mouth guard, mouth guards composed of many types of materials reduce the number of fractured teeth and head acceleration. A meta-analysis of the studies in their systemic review indicated that the risk of an orofacial sports injury was 1.6-1.9 times higher when a mouth guard was not worn.

The recommendation of mouth guard use for prevention of orofacial injuries is commonly met with a concern that wearing a mouth guard would be uncomfortable and may hinder performance. This lead to research with a focus on whether mouth guard use has a negative effect on performance, in particular, a custom-fitted mouth guard (individually made to specifically fit the athlete's mouth) and a self-adapted mouth guard (boil-and-bite mouth guards and stock mouth guards that are generically made and then adapted by the athlete to be more specific to their mouth) are compared to no mouth guard use.

No observation of a negative impact on performance

Lee-Knight, Bell, Faulkner, and Schneider, (1991) reviewed mouth guard use and concluded that there was apparent lack of negative effects on physical performance with the use of custom-fitted mouth guards.

One of the areas of concern with mouth guard use is the effect the mouth guard will have on breathing and therefore how mouth guard use may affect the cardiorespiratory ability of the athlete. Rapisura, Coburn, Brown, and Kersey, (2010) used separate maximal cycle ergometer tests with either a mouth guard or no mouth guard to investigate the effects of mouth guard use on physiological variables in women. They used a self-adapted mouth guard and concluded that athletes should be encouraged to use mouth guards without fear of negative aerobic performance effects.

This advice is supported by Kececi, Cetin, Eroglu, and Baydar, (2005) who evaluated the effect of custom-made mouth guards on the ventilatory gas exchange effects of taekwondo athletes. To determine the effect of mouth guard use during exercise, they measured oxygen consumption (VO_2) with a portable gas analysis system while an exercise tolerance test with a shuttle run test protocol was performed. They compared with and without mouth guard values and found no significant effect, concluding that taekwondo athletes can use custom-made mouth guards without negative effects on their aerobic performance capacity.

No impact on performance

Collares, Correa, Silva, Hallal, and Demarco, (2013) assessed the influence of custom-fit mouth guards on the aerobic performance of soccer and futsal players under 17 and concluded that the use of custom-fit mouth guards does not affect the aerobic performance of soccer and futsal U-17 players. The athletes' aerobic performance was assessed through the 20-meter shuttle-run test. None of the participants reported having used mouthguards before and levels of acceptance regarding breathing (P = .022) and communication (P = .002) increased after mouthguards usage. The mouthguards did not influence the aerobic performance of the players, considering both the total distance covered in the tests and the VO2 max. No effect on performance by mouth guard use was also stated by von Arx, Flury, Tschan, Buergin, and Geiser, (2008) who demonstrated that a custom-made mouth guard does not significantly affect or reduce maximum exercise performance of athletes when they tested athletes with a cardiorespiratory examination on a cycle ergometer, with and without mouth guards, to look at the effect of wearing a mouth guard on maximal exercise capacity and cardiopulmonary parameters at peak workload. Peak minute ventilation and oxygen uptake were not different during exercise with and without the mouth guard. Although it was not a significant value the maximum workload during spiroergometry was slightly elevated during exercise with the mouthguard (330.2 W) compared to exercise without the mouthguard (314.5 W).

Bourdin, et al., (2006) tested the influence of two types of maxillary mouth guards, a self-adapted (SA) and a custom-made model (CM), on various physiological parameters generally associated with performance in team sports. Visual reaction time, explosive power, ventilation at rest, and ventilation and oxygen consumption during submaximal and maximal exercise were measured in three randomized conditions: normal, with SA mouthguards, or with CM mouthguards. They also concluded that wearing a maxillary mouth guard does not affect the main physiological parameters generally associated with team sport performance.

Observations of a positive influence on performance

The suggestion mouth guard use has no effect on performance is contradicted by a study conducted by Garner, Dudgeon, Scheett and Mcdivitt, (2011) to assess the effects of custom-fitted mouthpieces on gas exchange parameters, including volume of oxygen consumption over time (VO_2), volume of oxygen consumption over time per kilogram of body weight (VO_2 /kg) and volume of carbon dioxide production over time (VCO_2). The results showed significant improvements ($P < .05$) in (VO_2), (VO_2 /kg) and (VCO_2) in the mouthpiece condition. They stated that the study findings showed that use of a custom-fitted mouthpiece resulted in improved specific gas exchange parameters and that they are pursuing further studies to explain the mechanisms involved in the improved endurance performance exhibited with mouthpiece use.
Morales, Buscà, Solana-Tramunt and Miró, (2015) conducted a study to determine the ergogenic acute effects of wearing a custom-made mouthpiece on oral airflow dynamics, 30-s Wingate Anaerobic Test performance parameters. They noticed that there were

significant differences ($P < 0.05$) between mouth guard and no-mouth guard conditions in mean power, peak power, time to peak, and rate to fatigue for the 30-s Wingate Anaerobic Test. In airflow dynamics, the maximum expiratory volume was significantly higher ($P < 0.05$) when comparing the mouth guard and the no mouth guard conditions in both forced and unforced conditions. They concluded that wearing a customized mouth guard improves anaerobic ability and increases forced expiratory volume and practitioners can help improve an athlete's performance in anaerobic activities where high intensity action might provoke jaw-clenching, contributing in reductions of lactate and fatigue, and improving ventilatory parameters.

Based from research demonstrating positive effects in exercise performance with the use of a mouthpiece, Garner and Mcdivitt, (2015) conducted a study to understand possible physiological explanations for these improvements. The study focused on differences in lactate levels after 30 minutes of endurance exercise with and without a mouthpiece, with computed tomography (CT) scans also taken of the cross-sectional area of the oropharynx in each participant with and without a mouthpiece. The CT scan results showed a significant difference in mean width (28.27 mm with the mouthpiece vs 25.93 mm without the mouthpiece, $P = .029$) and an increase in mean diameter of the oropharynx with a mouthpiece (12.17 mm vs 11.21 mm, $P = .096$) and the lactate levels were lowered with the mouthpiece at 1.86 mmol/L vs 2.72 mmol/L without mouthpiece. They stated that their research suggests that there is an improvement in endurance performance that may be linked to improved airway openings resulting from the use of a mouthpiece but stated the need for future studies to clarify the possible mechanisms for these exercise outcomes as well as to understand the optimal mandibular advancement to elicit these exercise improvements. This conclusion suggests that it is the position of the lower jaw that is the mechanism for the improvements.

Lower jaw position influence

The lower jaw position as the mechanism for improvement has been a suggestion from some researchers for some time. Schwartz & Novich, (1980) demonstrated that the most frequently used athlete's mouthpieces alter the relationship of the lower jaw to the upper jaw and expressed the need to have research on the design of the athlete's mouthpiece. They stated that statistics indicated a design change in the mouthpiece could be very advantageous to the athlete's performance and the mouthpiece should be viewed as an aid as well as a protector.

Although after a review of studies on performance enhancement because of mandibular orthopaedic repositioning appliances Kerr, (1986) stated that it is believed the placebo effect contributes to the findings of performance improvement but that long term studies are required to assess the claims of ergogenic enhancement utilising proper study design. Gelb, Mehta, & Forgione, (1996) acknowledged that much of the criticism of several reports, from 1970s to 1990s, of improved appendage muscle strength and athletic performance using a mouth guard alone or in conjunction with a splint, such as a mandibular orthopaedic repositioning appliance (MORA), to enhance athletic performance has been aimed at study designs, controls, periods of time, double blindness and the placebo effect. Although they stated that studies have been performed that meet the "gold standard" and the results favour the premise that jaw repositioning can enhance appendage muscular strength and athletic performance.

When reviewing the influence of the lower jaw position and performance, a lot of the research to date looks at aspects of muscular strength. Ferrario, Sforza, Serrao, Fragnito, and Grassi, (2001) investigated the hypothesis of a functional coupling between the stomatognathic motor apparatus and the muscles of other body districts, as well as between occlusal conditions and neuromuscular performance. Participants sustained with their dominant arm a dumbbell weighing 80% of their maximum while maintaining different jaw positions: mouth open, without dental contact; mouth close, with light dental contact; maximum voluntary clench; maximum voluntary clench on two cotton rolls positioned on the posterior mandibular teeth; maximum voluntary clench on one cotton roll positioned on the right/left-side posterior mandibular teeth. They concluded a morphologically altered occlusion does not always worsen the muscular performance of other body districts, and the use of occlusal supports (cotton rolls) is not always beneficial.

The view that lower jaw position does not affect performance was shared by Golem and Arent, (2015) who examined the effects of two over-the-counter jaw-repositioning mouth guards on muscular power and strength performance in college-aged male athletes. The test conditions consisted of a no-mouth guard control, a placebo mouth guard, a self-adapted jaw-repositioning mouth guard, and a custom-fitted jaw-repositioning mouth guard. Even though they found the custom-fitted jaw-repositioning mouth guard had significantly lower hip flexion than the no-mouth guard control and had significantly greater lumbar spine lateral flexion compared with the self-adapted jaw-repositioning mouth guard condition, they concluded the jaw-repositioning technique used in the design of these over-the-counter mouth guards did not affect performance. They also noted that negative effects were not observed indicating that mouth guard use does not impede performance.

With these studies finding no influence in lower jaw position on performance the claims of a placebo effect are possibly justified. Gage, Huxel Bliven , Bay, Sturgill, and Park, (2015) designed a cross-sectional study of 24 healthy adult weightlifters with normal occlusal relationships was to determine whether two self-fit performance mouth guards; a custom-fabricated, bilaterally balanced, dual-laminated mouth guard; and no mouth guard (control) differed in their effects on vertical dimension, muscle activation, and user preference during a 75% maximum power clean lift. The lower jaw position was determined by the thickness of the mouth guard. They found that participants preferred custom mouth guards over self-fit performance mouth guards and participants perceived that they were stronger when using a custom mouth guard.

The possibility that the lower jaw position does have an influence but not on every aspect of human performance was suggested by Dunn-Lewis, et al., (2012) when they carried out a study comparing a customized Power Balance performance mouth guard, a regular over the counter boil-and-bite mouth guard and a no mouth guard treatment condition during a sit-and-reach flexibility, medial-lateral balance, visual reaction time, vertical jump, 10-m sprint, bench throw, and plyo press power quotient tests. Heart rate and rating of perceived exertion was also recorded around the plyo press power quotient test. They found that bench throw power (watts) and force (newtons) were significantly higher ($P < .05$) under Power Balance performance mouth guard than either the over the counter boil-and-bite mouth guard and no mouth guard in both men and women. The plyo press power and force production were also higher with the Power Balance performance mouth guard than that for the other conditions, although only for the male participants. They observed no differences in flexibility, balance, visual reaction time, or sprint time and concluded that the PowerBalance performance mouth guard improves performance of upper-body loaded power exercises in both men and women and lower body power exercise in men without compromising performance on any other performance parameters.

These findings are supported by the outcomes of when Maurer, et al., (2018) questioned if the influence of the jaw position on postural control, body posture, walking and running pattern that has been reported in the literature could still be observed in maximal muscle activation. They used three different jump tests (squat jump, counter movement jump, and drop jumps from four different heights) and three maximal strength tests (trunk flexion and extension, leg press of the right and left leg) on participants during four different dental occlusion conditions and an additional familiarization condition. They observed that occlusion conditions with a relaxation position and with a myocentric condylar position showed significantly higher values for several tests compared to the neutral condition and the maximal occlusion position. Significance ($P < .05$) was found in the squat jump, countermovement jump, the drop jump from 32cm and 40cm, trunk extension, leg press force and rate of force development. They concluded that the influence of occlusion splints on rate of force development (RFD) and maximal strength tests could be confirmed.

Again, the influence on only some aspects of human performance was seen by Cetin, Keçeci, Erdoğan, & Baydar, (2009) when they studied the influence of custom-made mouth guards on strength and anaerobic performance of taekwondo athletes. They performed tests with or without custom-made mouth guards and observed no significant differences between the two conditions in 20 m sprint time, jumping tests, handgrip strength, isometric leg or back strength. Although they did observe that peak power and average power in Wingate Anaerobic Test and Hamstring Isokinetic Peak Torque significantly ($P < 0.05$) increased as a result of wearing a mouth guard.

The observation of a significant ($P < 0.05$) increase in average power in Wingate Anaerobic Test was contradicted when Fischer, Weber, and Beneke, (2017) tested the effects of a neuromuscular fitted dental splint in comparison with a habitual verticalizing splint and a no-splint condition on cycling sprint performance in the Wingate Anaerobic Test (WAnT). They found no differences between any splint conditions in any aspect of WAnT performance (time to peak power, peak power, minimum power, power drop, and average power. They concluded that irrespective of habitual verticalization or myocentric positioning, dental splints have no effects on any aspect of WAnT performance.
Drum, Swisher, Buchanan, and Donath, (2016) questioned the recommendation of a custom bite-aligning mouth guards for performance enhancement after conducting a 3-armed, randomized, controlled crossover trial investigating the difference of wearing a personalized or custom-made, a standard boil and bite, and no mouth guards on general fitness parameters in experienced collegiate football players. They recommended the need for further studies with larger sample sizes, gender comparison, and (sport) discipline-specific performance testing.

Sports Specific

Sport-specific performance testing of the influence of lower jaw position has been carried out. Egret, Leroy, Loret, Chollet, and Weber, (2002) stated that many athletes with or without occlusal problems are now using mandibular orthopedic repositioning appliance (MORA) supposedly to optimize their performance. They conducted a study to analyze if the use of the MORA could influence the stability of the kinematic pattern in golf swing stating the results indicated that the speed of the golf swing with MORA was more regular than the speed without the appliance.

The positive influence of a change in lower jaw position was also demonstrated by Pae, Yoo, Noh, Paek, and Kwon, (2012) when they carried out a study to determine the effect of stabilization splints and mouth guards on the athletic ability of professional golfers. The participants performed four trials of ten driver swings and ten putts with or without a stabilization splint (control group) or mouth guard. The drive distance, club head speed, initial ball speed, and putting accuracy were compared and analyzed before and after the application of equal bilateral molar occlusion. They found when the bilateral molar occlusion was applied using a mouth guard or stabilization splint, the club head speed and driving distance in the presence of the oral appliances were significantly ($P < 0.05$) increased compared with those without the presence of either appliance. They also observed that the initial ball speed and putting accuracy in the presence of these appliances were increased compared with those without the presence of an appliance. Although they found when the mouth guards or stabilization splints were adjusted to result in unilateral molar occlusion, the club head speed and driving distance in the presence of the appliances were significantly decreased compared with those that were obtained without these appliances. They concluded, the occlusion stability that results from stabilization splints and mouth guards is thought to increase the club head speed and driving distance in professional golf players.

The influence on cycling performance was reviewed when Piero, et al., (2015) evaluated the influence of a custom-made mouth guard (Parabite Malpezzi) on maximal and submaximal physiological parameters related to performance in road cycling. They concluded that results provide support for cyclists to correct jaw posture that may improve their exercise performance.

Maurer, et al., (2015) designed a study to identify the effect of lower jaw positions on running behaviour according to different dental occlusion positions. Kinematic data of the subjects were collected using an eight-camera Vicon motion capture system while performing five running trials per test condition (four different dental occlusion conditions in random order). They observed within individual subjects different running patterns could be identified for the four splint conditions. The splint conditions lead to a more symmetrical running pattern than the control condition. They concluded that the influence of an occlusal splint on running pattern can be confirmed and wearing a splint increases the symmetry of the running pattern. They noted that the change of the movement pattern between the neutral condition and any of the three splint conditions was significant within subjects but not across subjects, therefore although the dental splint has a measureable influence on the running pattern, subject's individuality has to be considered when choosing the optimal splint condition for a specific subject.

The athletic performance-lower jaw position connection

With the growing evidence of some link between performance and lower jaw position researchers have tried to understand the connection. Some looked at the athlete's bite (occlusion) as the connection. Jung, Chae, and Lee, (2013) looked at the effects of occlusal stability to identify action mechanisms of mouth guards, known to have a modulatory effect on limb muscle function. They reviewed five different lower jaw positions and concluded uneven distribution of occlusal force might have some positive effects.

Others have looked at the mechanism of clenching the teeth together as the connection. Buscà, Morales, Solana-Tramunt, Miró, and García, (2016) investigated the effects of jaw clenching while wearing a customized bite-aligning mouthpiece (MP) on jump ability and isometric maximal strength tests in contrast to two other conditions: non-jaw clenching (NON-JAW) and jaw clenching without the mouthpiece (JAW).. They concluded the findings suggested that it is advisable to use a customized bite-aligning mouthpiece to improve strength and power performance. Ebben, Flanagan, and Jensen, (2008) assessed the effect of current activation potentiation by evaluating jaw clenching and its effect on the rate of force development (RFD), time to peak force (TTPF), and peak force (PF) during the countermovement jump. They tested fourteen subjects using the countermovement jump on a force platform while maximally clenching their jaw on a dental vinyl mouth guard (JAW) as well as without clenching their jaw by jumping with an open mouth (NON-JAW). They found that the RFD was 19.5% greater and the TTPF was 20.15% less in the JAW compared with the NON-JAW. They stated that the findings indicated that concurrent activation potentiation is manifested through jaw clenching during the countermovement jump and athletes may employ this strategy of maximally clenching their jaws to gain an ergogenic advantage during the countermovement jump.

There is also a suggestion that condition of the Temporomandibular Joint (TMJ) is a significant factor. Garner and Miskimin, (2009) carried out a study to determine if there were improvements in auditory and visual reaction time with the use of a boil and bite mouthpiece. Using a BIOPAC system, study participants were asked to respond to an auditory signal during 40 trials and in the visual reaction time test, participants were assessed on how quickly they responded to a computer cue for a total of 30 trials. The auditory results showed a significant improvement with the use of a mouthpiece (241.44

ms) vs without a mouthpiece (249.94 ms) and the visual results showed that participants performed slightly better with the mouthpiece (285.55 ms) vs without the mouthpiece (287.55 ms). They stated the findings suggested that the use of a mouthpiece positively affects visual and auditory reaction time and future studies should assess possible reasons for the improvements in auditory and visual reaction time with the use of a mouthpiece. Including the need to assess if there is a connection with these improvements and enhanced TMJ positioning due to suggestions that by improving TMJ positioning with an oral device, improves blood flow in the area of the TMJ, and is linked to the improved performance.

Improved airway volume and efficiency is another possible explanation. Zupan, et al., (2018) evaluated physiological responses associated with exercise using two different mouthpieces compared with not using a mouthpiece. Twenty-three subjects completed a battery of five physiological tests; the 1.5-mile run, sit and reach, anaerobic endurance, leg press, and bench press. Each test battery was completed under three conditions: wearing a PX3 Bite Regulator mouthpiece, wearing a mouth guard, or no mouthpiece. The PX3 resulted in significantly faster 1.5-mile run times and significantly longer anaerobic endurance runs compared with the mouth guard and no mouthpiece. The leg press lifts while wearing the PX3 were significantly greater than when wearing a mouth guard. There were improvements, but no significant differences for sit and reach and bench press. They concluded the increased performance with the PX3 could be a result of better jaw alignment and/or decreased resistance to airflow.

The individuality of the athlete is a factor that must be considered and no matter what the mechanism of any possible influence on performance the lower jaw position of an athlete should be assessed specific to that individual. This was echoed when Grosdent, O'Thanh, Domken, Lamy, and Croisier, (2014) investigated the influence of dental occlusion on knee muscle strength performance. Isokinetic quadriceps and hamstring strength were assessed in relation to three randomized jaw conditions: mouth closed in maximum intercuspidation without splint, mouth closed on a balanced splint which optimized contact over the dental arch, mouth closed on a piece of resin of 1 mm which created an imbalanced occlusion. The imbalanced occlusion created by the resin component corresponded to an average decrease of 9% in eccentric peak torque. The eccentric hamstring peak torques also showed a significant difference between measurements with splint and with resin (7% decrease when occlusion was imbalanced). They concluded that among asymptomatic females, artificial imbalanced occlusion induces immediate and significant alteration of knee eccentric muscle performances. They stated that occlusion examination should be undertaken on a regular and frequent basis for high-level athletes and for athletes using mouth guards, muscular performance assessments should be planned with and without the dental protection.

Individual lower jaw position assessment

There was further justification for individual assessment when Baldini, et al., (2012) reported a clinical case detailing a gnathological postural approach to a professional basketball player suffering from muscular problems related to the stomatognathic apparatus and a low back pain unresolved with the physiotherapy, which limited her performance. After the treatment which involved inserting an occlusal splint and physiotherapy sessions, they stated the patient no longer complained of low back pain problems and the symptoms associated with the stomatognathic apparatus improved considerably. Particularly after a force increase related to the quadriceps muscles was detected when the patient was wearing the occlusal splint during the tests carried out on an isokinetic machine. They concluded that all athletes must be analysed individually and carefully with clinical and instrumental analyses to consider the possible real effectiveness of an occlusal splint for improving postural structure and sports performance.

Lower jaw position for optimal performance

It is an accepted physiological axiom that muscles function optimally from their full resting length: a rested state (Guyton 1981). Neuromuscular occlusion is in harmony with relaxed, healthy muscles and properly functioning temporomandibular joints. It is a stable maxillo-mandibular position of dental occlusion arrived at by isotonic contraction of relaxed masticatory muscles, achieved by stimulation of those muscles on a trajectory (arc) beginning at a muscularly rested mandibular position (Cooper & Kleinburg 2008). Therefore, the lower jaw position in neuromuscular occlusion would represent the position when the muscles of mastication are at their full resting length and therefore function optimally.

Neuromuscular therapies are a broad approach to address musculoskeletal dysfunction, including myofascial trigger points (Chaitow & DeLany, 2008). The neuromuscular therapy used to relax mandibular elevator and depressor muscles is a neuromuscular stimulator (TENS device). The stimulator used is like other medical nerve mediated ultra-low frequency TENS devices used to affect relaxation of muscles. It delivers an intermittent minute, low voltage, low amperage, fixed rate neural stimulus simultaneously to all the masticatory muscles through the mandibular division of the trigeminal nerve applied over the mandibular coronoid notch (Elbo, Jonas & Kappert 2006). Electromyography (EMG) measures electrical activity in muscles at rest and in function. This measured activity aids in identification of the mandibular (lower jaw) rest position as a reference for the selection of the neuromuscular occlusion position, as well as evaluation of the quality of the dental occlusion through the analysis of patterns of muscle motor unit recruitment.

Therefore, it could be hypothesised that by using neuromuscular therapy to find the lower jaw position when in neuromuscular occlusion and stabilizing this position during function by wearing a bite specific mouth guard will allow the muscles to function optimally and maximise performance potential.

Conclusion

Research in the effect of mouth guard use and performance has developed over the years. The initial focus of research in this area was to look to see if there is a negative effect on performance from wearing a mouth guard to protect from orofacial injuries. The consensus was that there was no negative effect from a properly fitted and designed custom-fitted mouth guard. A view that a mouth guard could improve athlete performance started to emerge. Research in this area was conflicting. Some researchers stated that a mouth guard has no affect on performance and a larger number noting an improvement of certain aspects of athletic performance when wearing a mouth guard. A major issue with current research in this area is the inconsistency in the type of mouth guard used to review if wearing a mouth guard could have a positive effect on performance. The position of the lower jaw when wearing a mouth guard as a mechanism for a possible link to an improvement in performance has emerged in the more recent research. There is a lack of consensus in the current research of the mechanism or connection between lower jaw position and performance.

Reviewing the literature has lead to the question - does the position of the lower jaw effect human performance?

A study comparing athletic performance during two different lower jaw positions will help answer this question. The hypothesis is that a lower jaw position when in neuromuscular occlusion will maximise performance. The results of the study will be reviewed to determine if the lower jaw position had an effect on the participant's performance.

References for Paper A

Baldini, A., Beraldi, A., Nota, A., Danelon, F., Ballanti, F., & Longoni, S. (2012). Gnathological postural treatment in a professional basketball player: A case report and an overview of the role of dental occlusion on performance. *Ann Stomatol (Roma)., 3*(2), 51-58.

Bourdin, M., Brunet-Patru, I., Hager, P., Allard, Y., Hager, J., Lacour, J., & Moyen, B. (2006). Influence of maxillary mouthguards on physiological parameters. *Medicine & Science in Sports & Exercise, 38*(8), 1500-1504. doi:10.1249/01.mss.0000228952.44850.eb

Buscà, B., Morales, J., Solana-Tramunt, M., Miró, A., & García, M. (2016). Effects of jaw clenching while wearing a customized bite-aligning mouthpiece on strength in healthy young men. *Journal of Strength and Conditioning Research, 30*(4), 1102-1110. doi:10.1519/jsc.0000000000001192

Cetin, C., Keçeci, A. D., Erdoğan, A., & Baydar, M. L. (2009). Influence of custom-made mouth guards on strength, speed and anaerobic performance of taekwondo athletes. *Dental Traumatology, 25*(3), 272-276. doi:10.1111/j.1600-9657.2009.00780.x

Chaitow, L., & DeLany, J. (2008). *Clinical application of neuromuscular techniques* (2nd ed., Vol. 1). Edinburgh: Churchill Livingstone Elsevier.

Collares, K., Correa, M. B., Silva, I. C., Hallal, P. C., & Demarco, F. F. (2013). Effect of wearing mouthguards on the physical performance of soccer and futsal players: A randomized cross-over study. *Dental Traumatology, 30*(1), 55-59. doi:10.1111/edt.12040

Cooper, B., Kleinberg, I. (2008). Establishment of a temporomandibular physiological state with neuromuscular orthosis treatment affects reduction of TMD symptoms in 313 patients. *Journal of Craniomandibular Practice*, 26(2), 104-117.

Drum, S. N., Swisher, A. M., Buchanan, C. A., & Donath, L. (2016). Effects of a custom bite-aligning mouthguard on performance in college football players. *Journal of Strength and Conditioning Research, 30*(5), 1409-1415. doi:10.1519/jsc.0000000000001235

Dunn-Lewis, C., Luk, H., Comstock, B. A., Szivak, T. K., Hooper, D. R., Kupchak, B. R., . . . Kraemer, W. J. (2012). The effects of a customized over-the-counter mouth guard on neuromuscular force and power production in trained men and women. *Journal of Strength and Conditioning Research, 26*(4), 1085-1093. doi:10.1519/jsc.0b013e31824b4d5b

Ebben, W. P., Flanagan, E. P., & Jensen, R. L. (2008). Jaw clenching results in concurrent activation potentiation during the countermovement jump. *Journal of Strength and Conditioning Research, 22*(6), 1850-1854. doi:10.1519/jsc.0b013e3181875117

Egret, C., Leroy, D., Loret, A., Chollet, D., & Weber, J. (2002). Effect of mandibular orthopedic repositioning appliance on kinematic pattern in golf swing. *International Journal of Sports Medicine, 23*(2), 148-152. doi:10.1055/s-2002-20135

Elbo, O.S., Jonas, I.E., Kappert H.F. (2006). Transcutaneous electrical nerve stimulation (TENS): its short-term and long-term effects on the masticatory muscles. *Journal of Orofacial Orthopaedics*, 61(2), 100-111

Ferrario, V. F., Sforza, C., Serrao, G., Fragnito, N., & Grassi, G. (2001). The influence of different jaw positions on the endurance and electromyographic pattern of the biceps brachii muscle in young adults with different occlusal characteristics. *Journal of Oral Rehabilitation, 28*(8), 732-739. doi:10.1046/j.1365-2842.2001.00749.x

Fischer, H., Weber, D., & Beneke, R. (2017). No Improvement in sprint performance with a neuromuscular fitted dental splint. *International Journal of Sports Physiology and Performance, 12*(3), 414-417. doi:10.1123/ijspp.2016-0037

Gage, C. C., Huxel Bliven, K. C., Bay, R. C., Sturgill, J. S., & Park, J. H. (2015). Effects of mouthguards on vertical dimension, muscle activation, and athlete preference: A prospective cross-sectional study. *General Dentistry, 63*(6), 48-55.

Garner, D. P., & Mcdivitt, E. J. (2015). Effects of mouthpiece use on lactate and cortisol levels during and after 30 minutes of treadmill running. *The Open Access Journal of Science and Technology, 3*. doi:10.11131/2015/101148

Garner, D. P., Dudgeon, W. D., Scheett, T. P., & Mcdivitt, E. J. (2011). The effects of mouthpiece use on gas exchange parameters during steady-state exercise in college-aged men and women. *The Journal of the American Dental Association, 142*(9), 1041-1047. doi:10.14219/jada.archive.2011.0325

Garner, D. P., & Miskimin, J. (2009). Effects of mouthpiece use on auditory and visual reaction time in college males and females. *Compendium of Continuing Education in Dentistry, 30*(2), 14-17.

Gelb, H., Mehta, N. R., & Forgione, A. G. (1996). The relationship between jaw posture and muscular strength in sports dentistry: a reappraisal. *Cranio®, 14*(4), 320-325. doi:10.1080/08869634.1996.11745984

Golem, D. L., & Arent, S. M. (2015). Effects of over-the-counter jaw-repositioning mouth guards on dynamic balance, flexibility, agility, strength, and power in college-aged male athletes. *Journal of Strength and Conditioning Research, 29*(2), 500-512. doi:10.1519/jsc.0000000000000641

Grosdent, S., O'Thanh, R., Domken, O., Lamy, M., & Croisier, J. (2014). Dental occlusion influences knee muscular performances in asymptomatic females. *Journal of Strength and Conditioning Research, 28*(2), 492-498. doi:10.1519/jsc.0b013e3182a7665a

Guyton, AC., (1981). *Textbook of medical physiology* (6th ed.) Philadelphia: WB Saunders, 137.

Jung, J., Chae, W., & Lee, K. (2013). Analysis of the characteristics of mouthguards that affect isokinetic muscular ability and anaerobic power. *The Journal of Advanced Prosthodontics, 5*(4), 388. doi:10.4047/jap.2013.5.4.388

Kececi, A. D., Cetin, C., Eroglu, E., & Baydar, M. L. (2005). Do custom-made mouth guards have negative effects on aerobic performance capacity of athletes? *Dental Traumatology, 21*(5), 276-280. doi:10.1111/j.1600-9657.2005.00354.x

Kerr, I. L. (1986). Mouth guards for the prevention of injuries in contact sports. *Sports Medicine, 3*(6), 415-427. doi:10.2165/00007256-198603060-00003

Knapik, J. J., Marshall, S. W., Lee, R. B., Darakjy, S. S., Jones, S. B., Mitchener, T. A., . . . Jones, B. H. (2007). Mouthguards in sport activities. *Sports Medicine, 37*(2), 117-144. doi:10.2165/00007256-200737020-00003

Lee-Knight, C. T., Bell, R. D., Faulkner, R. A., & Schneider, V. E. (1991). Protective mouthguards and sports injuries. *Journal Canadian Dental Association, 57*(1), 39-41.

Maurer, C., Stief, F., Jonas, A., Kovac, A., Groneberg, D. A., Meurer, A., & Ohlendorf, D. (2015). Influence of the lower jaw position on the running pattern. *Plos One, 10*(8). doi:10.1371/journal.pone.0135712

Maurer, C., Heller, S., Sure, J., Fuchs, D., Mickel, C., Wanke, E. M., . . . Ohlendorf, D. (2018).

Strength improvements through occlusal splints? The effects of different lower jaw positions on maximal isometric force production and performance in different jumping types. *Plos One, 13*(2). doi:10.1371/journal.pone.0193540

Morales, J., Buscà, B., Solana-Tramunt, M., & Miró, A. (2015). Acute effects of jaw clenching using a customized mouthguard on anaerobic ability and ventilatory flows. *Human Movement Science, 44*, 270-276. doi:10.1016/j.humov.2015.09.008

Pae, A., Yoo, R., Noh, K., Paek, J., & Kwon, K. (2012). The effects of mouthguards on the athletic ability of professional golfers. *Dental Traumatology, 29*(1), 47-51. doi:10.1111/j.1600-9657.2012.01123.x

Piero, M., Simone, U., Jonathan, M., Maria, S., Giulio, G., Francesco, T., . . . Giovanni, G. (2015). Influence of a custom-made maxillary mouthguard on gas exchange parameters during incremental exercise in amateur road cyclists. *Journal of Strength and Conditioning Research, 29*(3), 672-677. doi:10.1519/jsc.0000000000000695

Rapisura, K. P., Coburn, J. W., Brown, L. E., & Kersey, R. D. (2010). Physiological variables and mouthguard use in women during exercise. *Journal of Strength and Conditioning Research, 24*(5), 1263-1268. doi:10.1519/jsc.0b013e3181d1572d

Schwartz, R., & Novich, M. M. (1980). The athlete's mouthpiece. *American Journal of Sports Medicine,* 8(5), 357-9.

Von Arx, T., Flury, R., Tschan, J., Buergin, W., & Geiser, T. (2008). Exercise capacity in athletes with mouthguards. *International Journal of Sports Medicine, 29*(5), 435-8.

Zupan, M. F., Bullinger, D. L., Buffington, B., Koch, C., Parker, S., Fragleasso, S., . . . Rasmussen-Woerner, S. (2018). Physiological effects of wearing athletic mouth pieces while performing various exercises. *Military Medicine, 183*(Suppl_1), 510-515. doi:10.1093/milmed/usx155

Paper B - Project research report in the style of an academic paper focussing on methods, findings and their assessment of relevance to field.

Effects of the position of the lower jaw on human performance in athletes

John Haughey[1]

[1] MSc student at University of Chester

Key Words: mouth guards, occlusion, sport, neuromuscular

Word Count: 4,144

Appropriate publication journal

The British Journal of Sports Medicine (BJSM) is a peer-reviewed medical journal in the fields of sports science and sports medicine. Considering this paper is looking at how the position of the lower jaw has an effect on human performance the BJSM would be an appropriate journal for the publication of this paper.

The BJSM's submission guidelines for an original article were considered when formatting this paper, in particular the word count, abstract structure, tables and figures limit, subheadings in the methods, results and discussion, and a summary box.

Abstract

The purpose of this study was to explore the influence of the lower jaw position during human performance. Two lower jaw positions were compared, the position of the lower jaw with the athlete's normal bite (habitual bite) and the position of lower jaw when the muscles of mastication are in a physiological rest position (neuromuscular bite). Participants completed a medicine ball putt (upper body power), vertical jump (lower body power), sit and reach (composite hamstring flexibility), passive knee flexion (hamstring muscle length) and star excursion balance (stability and balance) tests in each condition. Paired t-tests showed the neuromuscular bite had significant ($p < .05$) positive effect on performance compared to the habitual bite for each performance test. On average the neuromuscular bite provided an increase in lower body power of 5.8%, upper body power of 10%, hamstring flexibility of 14% and balance and stability of 4.8% compared to the normal bite.

This study provides evidence of the need for lower jaw position assessment of athletes. The assessment should become part of the normal screening and testing athletes undertake for athletic performance monitoring and injury prevention. The lower jaw position created by the bite which an athlete competes in, whether that is their normal bite or a bite created by a protective mouth guard or performance mouthpiece, should be assessed to ensure that no negative effect is being created and optimised to ensure the athlete can get any possible positive effect on performance from their lower jaw position.

Introduction

The main reason for mouth guard use by athletes is for the protection of the orofacial region from trauma during training and competition. Current research suggests that the risk of an orofacial sports injury is 1.6-1.9 times higher when a mouth guard is not worn. The positive protective properties of mouth guard use are met with a concern that mouth guard use could have a negative effect on performance if the athlete finds the mouth guard uncomfortable to wear or if the mouth guard hinders breathing. Research that has investigated the possibility of a negative impact on performance by mouth guard use has formed the general conclusion that a properly designed and fitted mouth guard has no negative impact. Some of this research showed positive impacts on performance which has caused a growing interest in whether mouth guard use could have a positive influence on athletic performance.

Summary

- *Lower jaw position has an affect on human performance*
- *Significant improvement in upper body power, lower body power, hamstring flexibility and balance and stability with a physiological rest lower jaw position*
- Lower jaw position assessment of athletes should become a vital part of the medical and sport science screening and testing athletes undergo for athletic performance monitoring and injury prevention

Unlike the protective abilities of a mouth guard, current research has not lead to a consensus on whether mouth guard use can have a positive impact on performance. An issue with the current research is the inconsistency in the type of mouth guard used. When an athlete wears a mouth guard it has a changing effect on their oral environment. The mouth guard takes up free space in the mouth and changes the position of the lower jaw by not allowing the lower teeth to bite against the top teeth.

This research project will address the question, does the position of the lower jaw have an effect on human performance? by reviewing mouth guard effect on human performance using a mouth guard that will take into account the influence of a mouth guard on free space in the mouth and the position of the lower jaw. A mouth guard was individually designed to meet the recommended protective properties of the athlete's sport, meet the fit and design recommendations to prevent a negative impact, place the lower jaw in a position that correlates with the physiological rest position of the muscles of mastication, and place the lower jaw in a position that improves free space in the mouth.

Athletes then underwent athletic testing in two conditions, with the mouth guard in and biting into the bite position individually designed into the mouth guard (neuromuscular bite), and biting in their normal (habitual bite) biting position.

Methods

Study Design

To answer the question if the position of the lower jaw has an effect on human performance a repeated meaures study was carried out on athletes comparing the two different lower jaw positions while they undergo athletic testing. A repeated measures study was chosen due to its benefits of comparing change within a subject. Guo, Logan, Glueck, and Muller, (2013) stated that collecting repeated measurements of key variables can provide a more definitive evaluation of within-person change across time.

Different testing conditions

The two different jaw positions were the participant's normal bite (habitual bite) and the mouth guard bite (neuromuscular bite). The normal bite was determined by instructing the participant to bite their teeth together during testing. The mouth guard bite was determined by instructing the participant to bite into the mouthguard during testing.

The lower jaw position when biting (neuromuscular bite) into the mouthguard was determined by using the principles of physiological-based dentistry (neuromuscular occlusion). Neuromuscular occlusion is in harmony with relaxed, healthy muscles and properly functioning temporomandibular joints. It is a stable maxillo-mandibular position of dental occlusion arrived at by isotonic contraction of relaxed masticatory muscles, achieved by stimulation of those muscles on a trajectory (arc) beginning at a muscularly rested mandibular position (Cooper & Kleinburg 2008). The neuromuscular therapy used to relax mandibular elevator and depressor muscles is a neuromuscular stimulator (TENS device). Electromyography (EMG) measures electrical activity in muscles at rest and in function.

After using a TENS machine to allow the relaxation of the muscles of mastication a lower jaw position was recorded using surface electromyographs (sEMGs) on the muscles of mastication. This measured activity aids in identification of the mandibular (lower jaw) rest position as a reference for the selection of the neuromuscular occlusion position. A bite position that correlates to a position where the muscles of mastication are indicating on the sEMGs that they are at a physiological rest position was recorded.

A custom-fitted pressurized thermoforming maxillary mouth guard was then made at the recommended thickness for the participant's sport. The mouthguard was trimmed to ensure no negative effect is experienced by the athlete while wearing the mouthguard. The mouth guard had bite marks on the surface opposing the lower teeth which allowed the participant to bite into the mouth guard during testing. The position of the lower jaw when biting into the bite marks on the mouthguard replicated the recorded physiological rest position of the lower jaw.

Types of tests and equipment used

Three different athletic attritubes were chosen, power, flexibility and balance and stability.

An upper body power and lower body power test was selected due to the correlation of power output and sports performance. Hamstring flexibility testing was chosed due to hamstring injuries being one of the most common sporting injuries and the fact that injuries have a clear negative effect on performance. Balance and stability testing was selected to the proximity of the Temporomandibular Joints (TMJs) and the balance control systems in the ears and the need for balance and stability in most sporting movements.

The performance tests involved in this study to test these three athletic attritubes were chosen for their reliability, their specificity to functional tasks in sport and their ease to conduct at different locations. The tests used to review any effect on power were the Vertical Jump (VJ) using a digital jump mat, the Just Jump System, for lower body power and the Seated Medicine Ball Put using an inclined bench press and 9kg medicine ball for upper body power. The VJ test was used to test lower body power due to the fact that the results of the test are directly applicable to sports that require jumping and the ease of test administration. The seated medicine ball put is the most frequently used field test for upper body power due to the movement being specific to functional tasks in sport (Clemons, Campbell, & Jeansonne 2010). To review any effect on hamstring flexibility a composite hamstring test and an isolated muscle length hamstring test was used. The sit-and-reach test was used as the composite test and the passive knee extension test was used as the isolated muscle length test of each hamstring muscle. The posteromedial directional movement (Olmsted-Kramer, 2006) with each leg in the Star Excursion Balance Test (SEBT) was tested using a Movement Assessment Tool (The MAT) by Movement Assessment Technologies to determine any affect on balance and stability.

Sample group

The athletes involved in the study were male native English speakers from Ireland. The athletes were from three different sports where it is either compulsory or common practice to wear a mouth guard; gaelic football, field hockey and boxing. The athletes were either international level amateur athletes or professional athletes in their chosen sport.

Setting

Participants attended two sessions. The first session involved the athlete attending the dental surgery of the researcher. At this session the participants got impressions of their upper and lower dental arches and the lower jaw position for the neuromuscular bite was taken to allow fabrication of the custom-fitted neuromuscular mouth guard. The second session was the performance testing session. Testing on the two lower jaw conditions (normal bite and mouth guard bite) was conducted in a gym environment relevant to the participant.

Testing

Each participant performed the tests under the two conditions, biting with and without the mouthguard, in the same session so the two different lower jaw positions could be compared for each participant.

The order of the testing was designed to allow adequate recovery time in between power testing, >2 minutes. Participants would do one test in one lower jaw condition and then repeated the test in the second lower jaw condition. The condition that the participate completed the test in first was alternated between participants. That is, the first participant carried out the test first with their normal bite and then repeated the test with their mouth guard bite. Then when the second participipicant was tested they carried out the test first with their mouth guard bite and then repeated the test with their normal bite. The third participant then replicated the first participant's testing protocol and the fourth replicated the second participant's testing protocol and so forth.

Measurements

- Lower Body Power

A digital contact jump mat, the just jump system, was the only equipment used in the lower body power test.

A standard countermovement vertical jump test was used to assess lower body power. A contact mat was used to record results. The test required the participant to perform rapid countermovement by quickly descending into a squat (i.e., flexion of hips and knees, and forward and downward movement of the trunk) while keeping their hands placed on their hips. This rapid countermovement was immediately followed by a maximal jump. The participant was instructed to bite down bringing their lower teeth in contact with either their upper teeth or mouth guard for the duration of the test. After initial familiarization of the test procedure and the contact mat the participant did three sub-maximal effort jumps to fully acclimatise to the test. A 2-minute rest period was used to allow recovery between test jumps. Three test jumps were recorded for each condition with the mean of the three scores used as the test score.

- Upper Body Power

Equipment used to test upper body power was a 45 degree incline bench, a 9 kilograms medicine ball (Clemons, Campbell, & Jeansonne 2010), a marking pen and a measuring tape.

The participant was asked to seat comfortably on the incline bench and their feet flat on the floor and the medicine ball against their chest. Grasping the medicine ball with both hands, one on each side, the participants were asked to bite down bringing their lower teeth in contact with either their upper teeth or mouth guard for the duration of the test. Without any additional bodily movement, the participants propelled the ball in a straight line. After initial familiarization with the bench orientation and putting procedure, the participant performed three sub-maximal trails with the medicine ball. A 2-minute rest period was used to allow recovery between test throws. Three test throws were recorded for each condition with the mean of the three scores used as the test score.

- Hamstring flexibility

Composite hamstring flexibility was tested using the sit-and-reach test. The participant assumed a long sitting posture position on the mat with their knees at the 0 mark. After an initial familiarization with the sit-and-reach test, the participant reached forward with both hands as far as possible without letting their knees flex. The participants were asked to bite down bringing their lower teeth in contact with either their upper teeth or mouth guard for the duration of the test. A score was given by the most distant point on the mat reached by both hands for each condition

The passive knee flexion test was used as an isolated hamstring muscle length test. Participants assumed a supine position and with hip flexion at 90 degrees the range of flexion in each knee was recorded passively by the researcher for each condition. The participants were asked to bite down bringing their lower teeth in contact with either their upper teeth or mouth guard for the duration of the test. A score was given by the maximum degree of flexion achieved.

- Balance and Stability

The Star Excursion Balance Test (SEBT) in the posteromedial direction (Olmsted-Kramer, 2006) using a Movement Assessment Tool (The MAT) by Movement Assessment Technologies to record the scores was used to test balance and stability. Each particpant placed one foot in the middle of the star in the correct direction to allow the reach leg to move down the scoring line in a posteromedial direction from the standing leg. The participant was asked to bite down bringing their lower teeth in contact with either their upper teeth or mouth guard for the duration of the test. The participant then reached with the non-support leg as far as possible down the scoring line making a light tap of the scoring line and returning to the centre of the star. The participants were first asked to do six practice trials (Kinzey & Armstrong 1998) and then were tested in each condition for each leg.

Data Analysis

The sample size was 15. Due to the ratio data a parametric test was needed. No test for homogeneity of variance was required as only one group was involved in the study. As the study was a series of repeated measures tests within subjects of two conditions, paired t-tests were used to compare the results of the two conditions for each performance test. The data was assessed to ensure it met the assumption, for a paired t-test, of being normally distributed. The results were then reviewed to determine if the lower jaw position had an effect on the participant's performance.

Results

Due to the intensive schedules of the athletes and difficulties in finding suitable availability for testing a lower number of participants than had been planned undertook the athletic testing. In total 15 participants took part in the athletic testing. Data was recorded for the vertical jump (VJ) test, upper body ball put (BP) test, star excursion balance (SEBT) test, sit-and-reach (SR) test and the passive knee flexion (PKF) test from each participant for each testing condition, normal bite and mouth guard bite. Even though it was a smaller number of participants than original planned, the Shapiro-Wilk statistic showed there was enough data collected for each test to meet the assumption of being normally distributed, $p > .05$.

Lower Body Power

A paired t-test showed a significant difference ($p < .05$) in the results for the vertical jump (VJ) test between the normal bite (M = 46.29cm, SD = 6.44cm) and the mouth guard bite (M = 48.97cm, SD = 6.57cm).

Upper Body Power

A paired t-test showed a significant difference ($p < .05$) in the results for medicine ball putt (MBP) test between the normal bite (M = 255.49cm, SD = 53.6cm) and the mouth guard bite (M = 281.08cm, SD = 58.22cm).

Hamstring flexibility

- Sit and Reach

A paired t-test showed a significant difference ($p < .05$) in the results for sit and reach (SR) test between the normal bite (M = 51.6cm, SD = 11.92cm) and the mouth guard bite (M = 55.07cm, SD = 11.44cm).

- Passive Knee flexion test

A paired t-test showed a significant difference ($p < .05$) in the results for the right leg passive knee flexion (PKF) between the normal bite (M = 47.2 degrees, SD = 11.03 degrees) and mouth guard bite (M =56.4 degrees, SD = 11.52 degrees). A paired t-test showed a significant difference ($p < .05$) in results for the left leg passive knee flexion (PKF) between the normal bite (M = 45.47 degrees, SD = 9.36 degrees) and the mouth guard bite (M = 52.73 degrees, SD = 9.37 degrees).

Balance and Stability

A paired t-test showed a significant difference ($p < .05$) in the results for the right leg Star Excursion Balance Test (SEBT) test between the normal bite (M = 85.07cm, SD = 7.4cm9) and the mouth guard bite (M = 88.87cm, SD = 7.14cm). A paired t-test showed a significant difference ($p < .05$) in the results for the left leg Star Excursion Balance Test (SEBT) test between the normal bite (M = 84.27cm, SD = 7.77cm) and the mouth guard bite (M = 88.5cm, SD = 7.58cm).

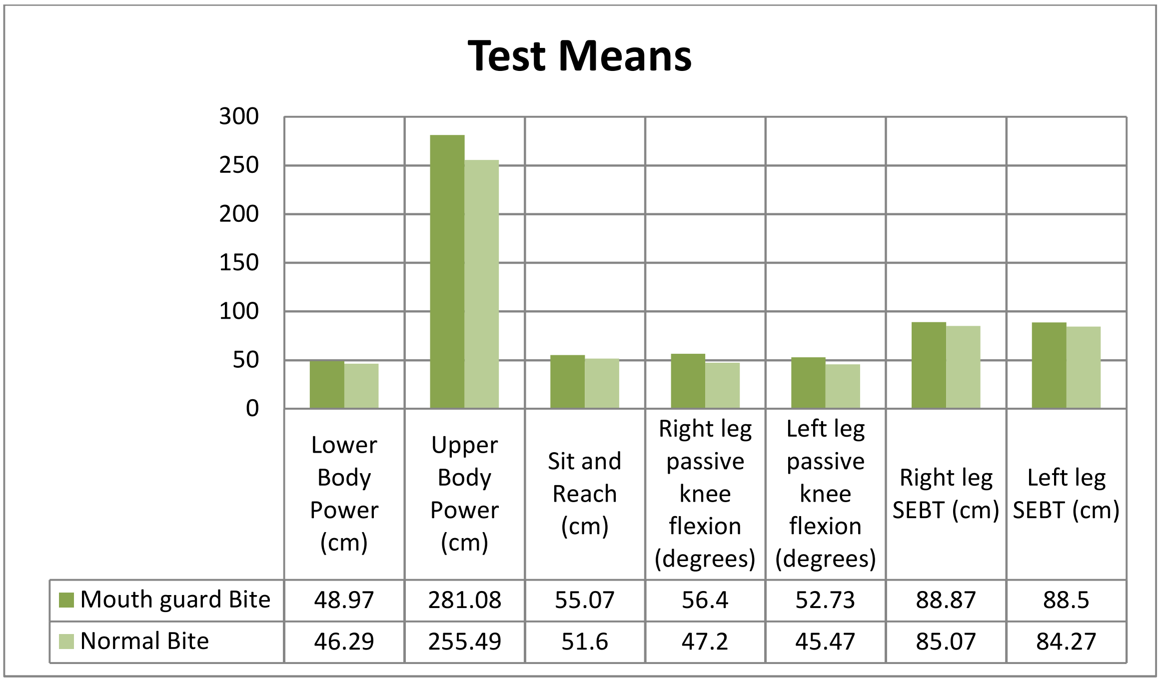


Figure 1 Test Means Comparison

A paired samples t-test was conducted to compare the data for each test condition, normal bite and mouth guard bite, from the VJ, BP, SEBT, SR and PKF tests. The paired sample t-tests showed that a change in the lower jaw position created by the different test conditions had a significant effect, $p < .05$, for each athletic test.

Reviewing the test means, Figure 1 above, the mouth guard bite provided an increase in lower body power of 5.8%, upper body power of 10%, hamstring flexibility of 14% and balance and stability of 4.8% compared to the normal bite.

Discussion

This research aimed to answer the question - does the position of the lower jaw effect performance? The results of this study strongly suggest that the position of the lower jaw influences performance. Not only was there an influence on performance but there was a significant positive effect on the participant's performance scores with their mouth guard bite compare to their normal bite.

Limitations

There was also a consideration of assessing a third condition at the testing, the participant's current mouth guard. Due to the inconsistency in the type of mouth guard and the inability to define the position of the lower jaw for each participant's current mouth guard this was unachievable.

Another limitation was the need for some of the testing to be dependent on the researcher confirming the score.

Comparisons to current research

The changes to the hamstring muscle and the improvements in power seen in this study are consistent with the observations of (Cetin, Keçeci, Erdoğan, & Baydar, 2009) where they noticed that peak power and average power and Hamstring Isokinetic Peak Torque significantly increased as a result of wearing a mouth guard. The significant improvement in power supports Maurer, et al., (2015) conclusion that the influence of occlusion splints on rate of force development (RFD) and maximal strength tests could be confirmed

This research importantly contradicts the view of many past researchers who stated that a mouth guard has no effect on performance like Bourdin, et al., (2006) who concluded that wearing a maxillary mouth guard does not affect the main physiological parameters generally associated with team sport performance.

The results provide further evidence to support the need for regular occlusion examination of high-level athletes and for athletes using mouth guards, and the need for muscular performance assessments to be planned with the athlete's mouth guard being worn as stated by Grosdent, O'Thanh, Domken, Lamy, & Croisier, (2014).

Possible explanation for significant positive athletic performance results

As discussed earlier a mouth guard has two influences on the oral environment when worn, an influence on free space in the mouth and an influence in the lower jaw position. The mouth guard used in this study was designed to have a minimal negative impact on free space in the mouth by being as thin and as small as possible in the lingual (tongue) side of the teeth therefore having minimal impact on the space available for tongue posture. The mouth guard was also designed to place the lower jaw in a position where the muscles of mastication were at a physiological rest. The bite position allowed the muscles of mastication to function more efficiently as muscles function optimally from their full resting length (Guyton 1981). This position in every participant was more vertical and anterior to their current bite therefore it created more free way space in the mouth allowing more available space for tongue posture during athletic performance. The mouth guard bite position also allowed for decompression of the temporomandibular joints (TMJs) due to the increase in vertical position of the posterior teeth with the mouth guard bite compared to the normal bite. These changes can be viewed by a radiograph as in Figure 2.

With the mouth guard bite the amount of free space available for tongue posture improves allowing the tongue to posture in a more anterior position. This improves the space available in the airway, figure 2. The physiological bite position in the mouth guard bite and the improved airway space created allows the head position to improve and creates a better cervical spine curvature, figure 2.

By using neuromuscular therapies to find the physiological rest position of the lower jaw and stabilising the lower jaw in this position by using a bite position in a mouth guard we can create an improved tongue position allowing improved airway space, a better head position and C-spine curvature and we also allow decompression of the TMJs.

The concept of kinetic chains could help explain how the lower jaw position can influence the musculature not directly corrected to the lower jaw, for example the hamstring muscles. Each kinetic chain includes the fascia and all the soft tissues, as well as the periosteum of the skeletal system and the nervous tissues, any movement of one part will have a lesser or greater effect on all other body parts within its kinetic chain. If one link in the chain does not operate efficiently due to abuse, overuse, disuse, or neural inhibition, the result will involve a change in function and structure throughout the entire chain. (Starlanyl & Sharkey, 2013). Therefore, the improvement of physiological state of the muscles of the head and neck in the mouth guard position would remove any lesser effect the habitual (normal) bite has on the kinetic chains. This would help explain the some of the benefits to athletic performance from a change in the lower jaw position.

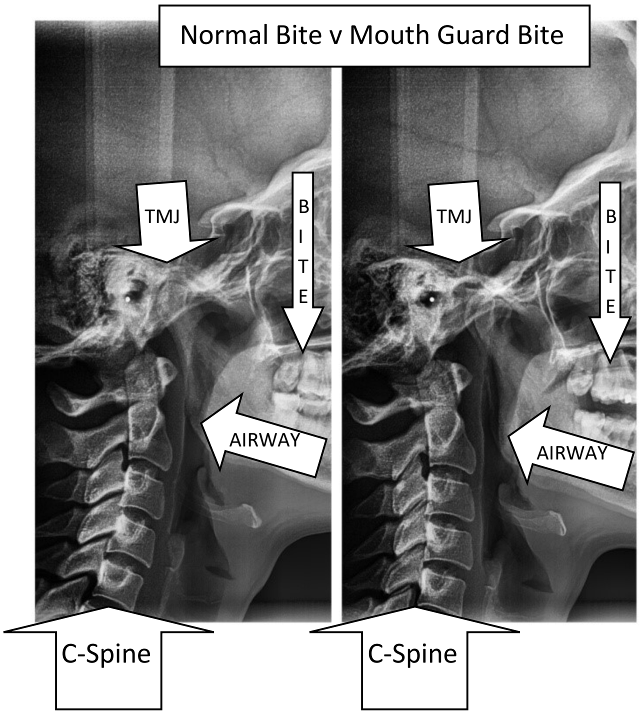


Figure 2

Recommendations for future research

This study supports the belief that the lower jaw position has a significant affect on physical performance. Due to the lack of research and understanding in this area further studies are needed to confirm the importance of assessing the lower jaw position in athletes and provide a clear understanding of how the lower jaw position influences performance.

Conclusion

This study demonstrated how a mouth guard can have a positive affect on athletic performance by having a specific biting position for the lower jaw that was better than the athlete’s normal bite. It would be reasonable to suggest that a mouth guard that creates a lower jaw position that is not as good from a physiological aspect as the athlete’s normal bite would then have a negative effect on that athlete’s performance. Mouth guards are generally made and worn for protective purposes. They are designed to be a certain thickness to help protect the teeth and oral cavity from trauma. Little or no consideration is given to the lower jaw position that the athlete is forced to create with the mouth guard in position.

The results of this study provide evidence of the need for lower jaw position assessment of athletes. The assessment should review whether a better lower jaw position can be created for performance and should become part of the normal screens and tests athletes undertake for athletic performance monitoring and injury prevention. If the athlete currently wears a mouth guard to compete then the assessment should include the lower jaw position the current mouth guard is creating in the athlete.

In summary, the lower jaw position created by the bite which an athlete competes in, whether that is their normal bite, bite created by a protective mouth guard, or the bite created by a performance mouthpiece, should be assessed to ensure that no negative effect is being created. The bite should also be assessed to review if it can be optimised to ensure the athlete can get the maximum positive affect on performance from their lower jaw position.

References for Paper B

Bourdin, M., Brunet-Patru, I., Hager, P., Allard, Y., Hager, J., Lacour, J., & Moyen, B. (2006). Influence of maxillary mouthguards on physiological parameters. *Medicine & Science in Sports & Exercise, 38*(8), 1500-1504. doi:10.1249/01.mss.0000228952.44850.eb

Cetin, C., Keçeci, A. D., Erdoğan, A., & Baydar, M. L. (2009). Influence of custom-made mouth guards on strength, speed and anaerobic performance of taekwondo athletes. *Dental Traumatology, 25*(3), 272-276. doi:10.1111/j.1600-9657.2009.00780.x

Clemons, J.M., Campbell, B., & Jeansonne, C. (2010). Validity and reliability of a new test of upper body power. *Journal of Strength and Conditioning Research*, 24(6), 1578-1565.

Cooper, B., Kleinberg, I. (2008). Establishment of a temporomandibular physiological state with neuromuscular orthosis treatment affects reduction of TMD symptoms in 313 patients. *Journal of Craniomandibular Practice*, 26(2), 104-117.

Grosdent, S., O'Thanh, R., Domken, O., Lamy, M., & Croisier, J. (2014). Dental occlusion influences knee muscular performances in asymptomatic females. *Journal of Strength and Conditioning Research, 28*(2), 492-498. doi:10.1519/jsc.0b013e3182a7665a

Guo, Y., Logan, H. L., Glueck, D. H., & Muller, K. E. (2013). Selecting a sample size for studies with repeated measures. *BMC Medical Research Methodology, 13*(1). doi:10.1186/1471-2288-13-100

Guyton, AC., (1981). *Textbook of medical physiology* (6th ed.) Philadelphia: WB Saunders, 137.

Kinzey, S.J., & Armstrong, C.W. (1998). The reliability of the star-excursion test in assessing dynamic balance. *Journal of Orthopaedic & Sports Physical Therapy*, 27:356-360.

Olmsted-Kramer, L. C. (2006). Simplifying the star excursion balance test: analyses of subjects with and without chronic ankle instability. *Journal of Orthopaedic and Sports Physical Therapy*. doi:10.2519/jospt.2006.2103

Starlanyl, D., & Sharkey, J. (2013). *Healing through trigger point therapy: A guide to fibromyalgia, myofascial pain, and dysfunction*. Chichester, England: Lotus Pub.

Supporting documents

Appendix 1 - Participant information sheet

University of Chester

Participant information sheet

A study into the effects of different positions of the lower jaw on human performance in athletes in Ireland

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

This research is being undertaken on healthy athletes. The project is to find out if lower jaw position has an effect on human performance. The positions of the lower jaw will be habitual bite, position with current mouthguard in place and physiological rest.

After the recording of the physiological rest position of the lower jaw, a mouthguard will be manufactured that will recreate the physiological rest position when worn. Performance tests will be carried comparing results between habitual bite, current mouthguard being worn by the athlete and the new mouthguard.

Why have I been chosen?

You have been chosen because you are a healthy athlete.

Do I have to take part?

It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What will happen to me if I take part?

You will come to 2 sessions. The first will be the finding of your physiological rest position usually the TENS machine and the K-7 machine, this session will last 2hrs. The second session will be to undertake a series of performance tests with and without a mouthguard. No-one will be identifiable in the final report.

What are the possible disadvantages and risks of taking part?

There are no disadvantages or risks foreseen in taking part in the study.

What are the possible benefits of taking part?

You will get a physiological assessment of their lower jaw, will receive feedback on the results from the human performance testing and will receive a free neuromuscular mouthguard

What if something goes wrong?

If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, Dean of the Faculty of Life Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 00441244 513055.

Will my taking part in the study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

What will happen to the results of the research study?

The results will be written up into a report for the final project of my MSc. Individuals who participate will not be identified in any subsequent report or publication.

Who is organising the research?

The research is conducted as part of a MSc in Neuromuscular Therapy within the Department of Clinical Sciences and Nutrition at the University of Chester. The study is organised with supervision from the department, by John Haughey, an MSc student.

Who may I contact for further information?

If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

John Haughey, 1222713@chester.ac.uk

Thank you for your interest in this research.

Appendix 2 – Consent Form

University of Chester

Title of Project: A study into the effects of different positions of the lower jaw on human performance in athletes in Ireland**.**

Name of Researcher: John Haughey

Please initial box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐

3. I agree to take part in the above study. ☐

Name of Participant	Date	Signature

John Haughey

Researcher	Date	Signature

1 for participant; 1 for researcher

Appendix 3 - Coach/manager Information Sheet

A study into the effects of different positions of the lower jaw on human performance in athletes in Ireland

John Haughey

Study: To assess differences in performance in athletes with no mouthguard, neuromuscular mouthagurd and current mouthguard during testing.

Players Taking Part: Athletes who currently use a mouthguard

Player Involvement: Each player will take part in 2 sessions

Session 1: Taking the impressions needed to manufacture a neuromuscular mouthguard

Session 2: Testing the neuromuscular mouthguard against habitual bite and current mouthguard

Session 1 will take 2hrs and can be done remotely as the equipment is mobile. Suggested location for session 1 is the medical room base of the player. All that is needed at the location is 2 normal chairs, a table and 2 separate electrical sockets.

Suggested location of session 2 is the strength and conditioning gym of the athlete. Equipment will be supplied by researcher.

Aim and Objectives of MSc Research Project

Aim: To determine if the position of the lower jaw has an effect on human performance in athletes

Objectives: To provide evidence that the position of the lower jaw has an effect on human performance. To formulate a screening test that can be used by athlete medical teams to determine if an athlete's lower jaw position has the potential to affect their performance.

Tests to use in

1. **Range of Motion:** Cervical Spine and Lumbar Spine
2. **Forward Head Posture**
3. **Muscle Length Testing:** Isolated (Straight Leg Raise) and composite (sit and reach) test of the hamstring
4. **Power:** Lower Body (CMJ/VJ) and Upper Body (Medicine Ball Put)
5. **Balance:** Single Leg Stability Test

Appendix 4 – Health Screen

University of Chester

QUI DOCET IN DOCTRINA

Pre-test Questionnaire

A study into the effects of different positions of the lower jaw on human performance in athletes in Ireland

Researcher *: John Haughey*

Name:________________________________ Test date:________________

Contact number:____________________________ Date of birth:___________

In order to ensure that this study is as safe and accurate as possible, it is important that each potential participant is screened for any factors that may influence the study. Please circle your answer to the following questions:

1.	Has your doctor ever said that you have a heart condition *and* that you should only perform physical activity recommended by a doctor?	YES/NO
2.	Do you feel pain in the chest when you perform physical activity?	YES/NO
3.	In the past month, have you had chest pain when you were not performing physical activity?	YES/NO
4.	Do you lose your balance because of dizziness *or* do you ever lose consciousness?	YES/NO
5.	Do you have bone or joint problems (e.g. back, knee or hip) that could be made worse by a change in your physical activity?	YES/NO
6.	Is your doctor currently prescribing drugs for your blood pressure or heart condition	YES/NO
7.	Are you pregnant, or have you been pregnant in the last six months?	YES/NO
8.	Have you ever had any reactions to TENS treatment? Or have you any contraindications for TENS treatment, i.e. temporal arteritis, malignancy	YES/NO
9.	Have you injured your hip, knee or ankle joint in the last six months?	YES/NO
10.	Do you know of any other reason why you should not participate in physical activity?	YES/NO

Thank you for taking your time to fill in this form. If you have answered 'yes' to any of the above questions, unfortunately you will not be able to participate in this study.

Appendix 5 – Mouth guard Protocol Information Sheet

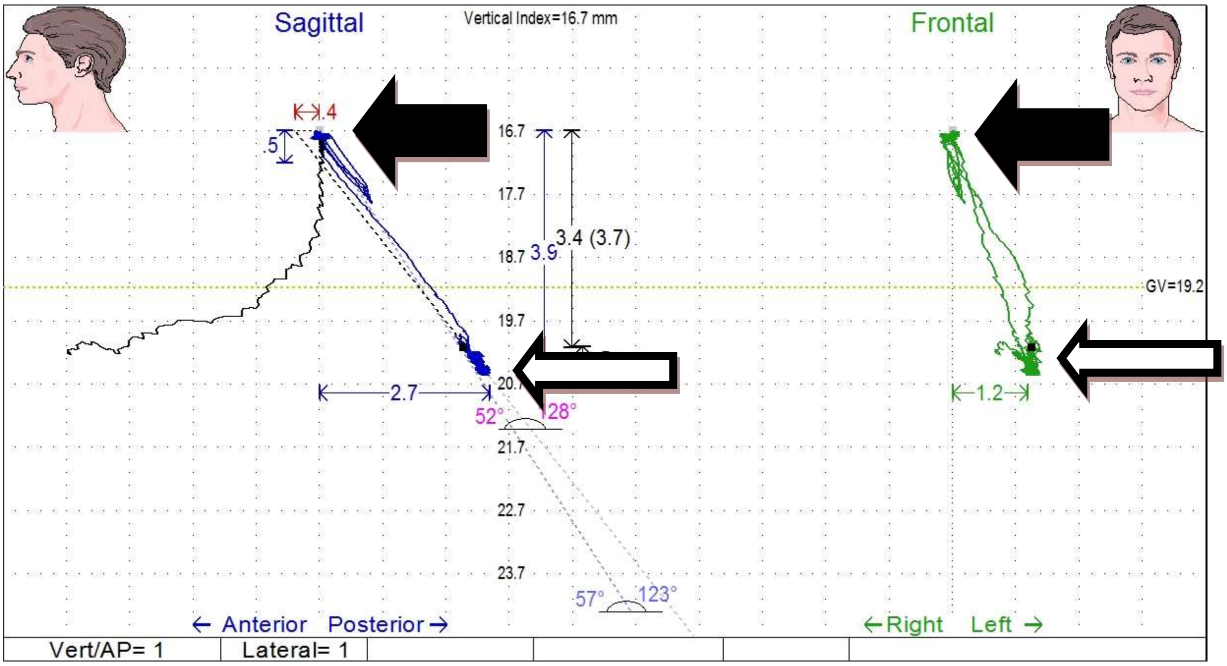
The neuromuscular mouthguard is made by using ultra-low frequency TENS to affect relaxation of the muscles of mastication and then using Scan 4/5 with the K-7 machine to record a neuromuscular physiologic rest position.

A J-5 myomonitor, which is a bilateral ultra-low frequency TENS machine, is used to stimulate the cranial nerve V, VII and IX for 60mins. This allows the relaxation of the muscles of mastication.

A K-7 machine is then used to find the neuromuscular rest position of the mandible. A K-7 machine has the ability to record, at the same time, the activity of the muscles of mastication and the movement of the mandible. Surface electromyography (sEMGs) duotrodes of the K-7 are placed on the temporalis, masters, digastics and sternocleidomastoids to record the activity of the muscles. A CMS (computerised mandibular scanner) is used to track the magnetic placed on the lower front teeth therefore making it possible to record the movements of the mandible in frontal and sagittal planes.

The TENS is used to achieve the physiological rest position of the mandible and a therapeutic neuromuscular occlusal position. After the 60mins of TENS on the muscles of mastication the patient had a Scan 4/5 with the K-7 machine traced. This is a scan which allows the comparison of the jaw movement to a habitual bite and the jaw movement at a neuromuscular rest position, which is achieve with the bilateral ultra-low frequency TENS therapy.

Example of a K-7 4/5 Scan



The K-7 scan 4/5 allows comparison of the mandible in a physiologic rest position (white arrows) to the position of the mandible in the habitual occlusion (black arrows).

A neuromuscular mouthguard is developed by using the Scan 4/5 from the K7 and recording a bite registration of the mandible in the physiologic rest position. Upper and lower impressions of the teeth are also taken.

Study casts of the maxilla and mandible arches are then poured up from the impressions and articulated by using the HIP (hamular notch to incisal papilla) plane to place the maxilla horizontal and perpendicular to gravity, then the bite registration of the physiological rest position of the mandible allows articulate the maxilla and the mandible to replicate the physiological rest position of the mandible. A neuromuscular mouthguard is then manufactured to allow the mandible to be stabilized in this position when worn in the mouth.

Appendix 6 – Measurement Protocol

ORDER OF TESTING

1. Warm Up
2. Upper Body Power familiarisation
3. Lower Body Power familiarisation
4. Muscle length testing – Sit and Reach test
5. Upper Body Power Test 1 (2mins rest before next test)
6. Lower Body Power Test 1 (2mins rest before next test)
7. Muscle length testing – Passive knee flexion
8. Upper Body Power Test 2 (2mins rest before next test)
9. Lower Body Power Test 2 (2mins rest before next test)
10. SEBT familiarisation
11. Upper Body Power Test 3 (2mins rest before next test)
12. Lower Body Power Test 3 (2mins rest before next test)
13. SEBT test
14. Upper Body Power Test 4 (2mins rest before next test)
15. Lower Body Power Test 4 (2mins rest before next test)
16. Cervical Spine ROM test – flexion, extension, lateral flexion
17. Upper Body Power Test 5 (2mins rest before next test)
18. Lower Body Power Test 5 (2mins rest before next test)
19. Cervical Spine ROM test – rotation
20. Upper Body Power Test 6 (2mins rest before next test)
21. Lower Body Power Test 6 (2mins rest before next test)
22. Forward Head Posture Test
23. Upper Body Power Test 7 (2mins rest before next test)
24. Lower Body Power Test 7 (2mins rest before next test)
25. Lumbar Spine ROM Test – flexion, extension
26. Upper Body Power Test 8 (2mins rest before next test)
27. Lower Body Power Test 8 (2mins rest before next test)
28. Lumbar Spine ROM Test – lateral excursion, rotation
29. Upper Body Power Test 9 (2mins rest before next test)
30. Lower Body Power Test 9 (2mins rest before next test)
31. Screening
32. Finish

RANGE OF MOTION

Cervical Spine – Rotation, Extension, Flexion, Lateral flexion

Equipment – CROM Deluxe

1. Participant Position – Sitting erect
2. Participant is instructed on the desired movements
3. CROM device is placed on the participant
4. Initial measurement is recorded
5. Participant carries out the required each action when requested
6. Final measurement is taken
7. ROM is recorded by subtracting the initial measurement from the final measurement.
8. Steps 3-7 are repeated for each action and then repeated for each testing condition, i.e. no mouthguard, NM mouthguard and current mouthguard

Actions

Flexion – active cervical flexion is performed while maintaining thoracic spine against back of chair

Extension – active cervical extension is performed while maintaining thoracic spine against back of chair

Lateral Flexion – active lateral cervical flexion is performed ensuring that the shoulders do not elevate during movement. No rotation, flexion or extension of cervical spine is allowed in bringing the ear as close as possible to shoulder.

Rotation – active cervical rotation is performed ensuring no trunk rotation during movement. No flexion, extension of lateral flexion of cervical spine is allowed. Initial measurement is set at 0 degrees on CROM before movement is undertaken.

Lumbar Spine - Rotation, Extension, Flexion, Lateral excursion

Equipment – BROM

1. Participant Position – Standing erect
2. Participant is instructed on the desired movements
3. BROM device is placed on the participant specific to the movement to be tested
4. Initial measurement is recorded
5. Participant carries out the required each action when requested
6. Final measurement is taken
7. ROM is recorded by subtracting the initial measurement from the final measurement.
8. Steps 3-7 are repeated for each action and then repeated for each testing condition, i.e. no mouthguard, NM mouthguard and current mouthguard

Actions

Flexion –

Placement of BROM: Landmarks are the spinous process of S1 and T12 vertebra. Place BROM flexion-extension unit with pivot point on spinous process of S1 vertebra and the tip of the moving arm at level of T12 spinous process.

Movement: Running both hands down the front of the legs, patient flexes spine through available ROM.

Extension –

Placement of BROM: Landmarks are the spinous process of S1 and T12 vertebra. Place BROM flexion-extension unit with pivot point on spinous process of S1 vertebra and the tip of the moving arm at level of T12 spinous process.

Movement: Placing hands on waist, participant extends spine through available ROM while keeping knees extended.

Lateral Flexion –

Placement of BROM: Landmark is the spinous process of T12 vertebra. Place centre of BROM lateral flexion-rotation unit firmly against participant's back so the feet of unit are in line with spinous process of T12. Position of unit is adjusted on the back of the participant until inclinometer reads 0 degrees.

Movement: Patient laterally flexes spine through available ROM by running hand down the side of the leg while keeping knees extended and does not bend trunk forward or backward. Lateral flexion-rotation unit is held in place by examiner during movement.

Rotation –

Placement of BROM: Landmarks are the spinous process of S1 and T12 vertebra. Place the magnetic reference over spinous process of S1 vertebra and place centre of BROM flexion-extension unit firmly against back so the feet of the unit are at the level of T12 spinous process and set the horizontal inclinometer at 0 degrees.

Movement: Holding rotation unit in place as the participant rotates spine through available ROM.

Muscle length testing of the Hamstring

Direct Measurement – Knee Extension Test

Equipment – Geniometer from BROM kit

1. The participant is in the supine position with hip flexed to 90 degrees. Contralateral lower extremity should be placed on support surface with knee fully extended.
2. Participant is instruction on the desired movement.
3. The examiner passively extends knee until firm muscular resistance to further motion is felt, all the time the participant is ensuring the contralateral lower extremity is placed on the support surface with knee fully extended.
4. A second examine places the goniometer with the stationary arm on the greater trochanter of femur, the axis on the lateral epicondyle of femur and the moving arm on the lateral malleolus
5. The maximum amount of knee extension is recorded.
6. Steps 1-5 are then repeated with the participant opposite leg.

Indirect Measurement – Sit and Reach Test

Equipment – Functional Movement Group mat.

1. The participant assumes the long sitting posture on the Functional Movement Group mat.
2. The position of the knees is measured on the mat and recorded as the initial measurement.
3. The participant then reaches forward with both hands as far as possible, not allowing the knees to flex.
4. The maximum distance the middle fingers can reach is measured on the mat and recorded as the final measurement.
5. Reach distance is recorded as final measurement minus initial measurement.

SINGLE LEG STABILITY - SEBT (posteromedial)

Equipment – Functional Movement Group Mat

1. The participant places his left foot on the circle with his heel on the centre of the circle and the foot pointed on the 45º line which allows the posteromedial movement of the right foot to move down the measuring line.
2. The participant takes 4 practice movements. The movement involves standing on the left leg reaching as far as possible with the right foot in the posteromedial direction and lightly tapping the mat.
3. The participant is tested in the 3 different testing conditions, i.e. no mouthguard, NM mouthguard and current mouthguard. The distance is recorded, three tests are performed and then averaged for each testing condition. The test is nullified and is repeated if the subject commits any of the following errors: makes a heavy touch, rests the foot on the ground, loses balance, or cannot return to the starting position under control.
4. Steps 1-3 are then repeated with the participant standing on the right foot.

POWER

Upper Body – Medicine Ball Put

Equipment – 9kg medicine ball, measuring tape, 45° incline bench, gymnastics chalk

1. 8m is measured from the bench on the floor
2. The participant sits on the bench and rests back on the inclined sit with feet flat on the floor
3. The participant then does 3 warm-up submaximal trials with the medicine ball
4. Without any additional bodily movement, he participant then throws the medicine ball as far at an optimal trajectory of 45° for maximal horizontal distance
5. Three attempts under the 3 testing conditions, i.e. no mouthguard, neuromuscular mouthguard and current mouthguard, will be undertaken with a minimum of 2 minutes rest in between throws

Lower Body – Vertical Jump Test

Equipment – Just Jump mat

1. The participant's weight is taken in kilograms
2. The participant is then allowed several trials to become familiar with the countermovement jump procedure
3. For a standard countermovement VJ test, the subject is not permitted to take any lead up steps. The test requires the subject to perform a rapid countermovement by quickly descending into a squat while swinging the arms down and backward. The rapid countermovement is immediately followed by a maximal jump on the Just Jump mat
4. Three attempts under the 3 testing conditions, i.e. no mouthguard, neuromuscular mouthguard and current mouthguard, will be undertaken with a minimum of 2 minutes rest in between jumps

Appendix 7 – Results recording sheet

Name	
Age	
Sport	

RANGE OF MOTION	**No mouthguard**		**NM mouthguard**		**Current mouthguard**	
Cervical Spine						
Rotation	R	L	R	L	R	L
Extension						
Flexion						
Lateral excursion	R	L	R	L	R	L
Lumbar Spine						
Rotation	R	L	R	L	R	L
Extension						
Flexion						
Lateral excursion	R	L	R	L	R	L

SINGLE LEG STABILITY	**No Mouthguard**		**NM Mouthguard**		**Current Mouthguard**	
SEBT (posteromedial)	R	L	R	L	R	L

FORWARD HEAD POSTURE	**No Mouthguard**	**NM Mouthguard**	**Current Mouthguard**

MUSCLE LENGTH TESTING	**No Mouthguard**	**NM Mouthguard**	**Current Mouthguard**
Hamstring			
Sit and Reach			
Passive Knee Flexion			

POWER	**No Mouthguard**	**NM Mouthguard**	**Current Mouthguard**
Upper Body			
Medicine Ball Put			
Lower Body			
Vertical Jump			

Appendix 8 – FREC approval

Faculty of Life Sciences

Research Ethics Committee

frec@chester.ac.uk

21/09/2015

John Haughey
Ballynanny Road
Banbridge

Dear John

Study title: ***Effects of different positions of the lower jaw on human performance in athletes***

FREC reference: ***1063/15/JH/CSN***

Version number: ***1***

Thank you for sending your application to the Faculty of Life Sciences Research Ethics Committee for review.

I am pleased to confirm ethical approval for the above research, provided that you comply with the conditions set out in the attached document, and adhere to the processes described in your application form and supporting documentation.

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
Application Form	1	April 2015
Appendix 1 – List of References	1	April 2015
Appendix 2 – Summary CV for Lead Researcher	1	April 2015
Appendix 3 – Participant Information Sheet [PIS]	2	August 2015
Appendix 4 – Participant Consent Form	1	April 2015
Appendix 5 – Information sheet/letters to other personnel	1	April 2015
Appendix 6 – Health Screen	1	April 2015

Appendix 7 – Description of mouth-guard procedure	1	April 2015
Appendix 8 – Measurement protocol	1	April 2015
Appendix 9 – Results recording sheet	1	April 2015
Appendix 10 – Screening recording sheet	1	April 2015
Response to FREC request for further information or clarification	1	August 2015

Please note that this approval is given in accordance with the requirements of English law only. For research taking place wholly or partly within other jurisdictions (including Wales, Scotland and Northern Ireland), you should seek further advice from the Committee Chair / Secretary or the Research and Knowledge Transfer Office and may need additional approval from the appropriate agencies in the country (or countries) in which the research will take place.

With the Committee's best wishes for the success of this project.

Yours sincerely,

Dr. Stephen Fallows

Chair, Faculty Research Ethics Committee

Enclosures: Standard conditions of approval.

Cc. Supervisor/FREC Representative